Species

Author Affiliation:
Department of Zoology, Faculty of Science, University of Peradeniya, Sri Lanka

✉**Corresponding author:**
Buddhika Weerakoon, 10, Dodamgolla, Menikhinna, Sri Lanka. 20170. +94713391713, buddhikavray@gmail.com

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Diversity and distribution of butterflies in Maragamuwa forest regeneration study site, Matale, Sri Lanka

Buddhika Weerakoon✉, Kithsiri Ranawana

ABSTRACT

Maragamuwa Forest Regeneration Study Site was established in a harvested eucalypt plantation (7^0 41' 39.16" N - 80^0 42' 31.58" E) in the intermediate zone of Sri Lanka Based on the age from the disturbance, two vegetation types could be identified as early secondary forest (ESF) and late secondary forest (LSF). Abundance, Occurrence and diversity of butterflies were monitored for two years. The Gamma (γ) diversity of the areas is 100 species in six families with four endemics. Highest abundance was recorded in ESF (n= 2963), while highest species richness was recorded in LSF (n= 76). Alpha (α) diversity of LSF was higher than ESF. A statistically significant difference in butterfly diversity was recorded in two forests (p<0.001). Several indicator species were identified for each forest type. Indicator species of ESF were small and indicators for LSF were large butterflies. Few new records to the region were identified during the study. Findings of the study showcase the value of long term studies and can be used as a fundamental tool for planning future studies and conservation actions.

Keywords: Diversity, Butterfly, Forest regeneration, indicator species, geographical range

1. INTRODUCTION

Sri Lanka is a continental island of 65,610 km² in extent, with three main climatic zones namely wet, intermediate and dry zone. Wet zone has the highest biodiversity and endemism (MOE, 2012). Butterfly fauna of the country is rich with 245 species of 6 families including 26 endemic species (Van der Poorten, 2012). The six butterfly families recorded in Sri Lanka are, Papilionidae, Pieridae, Nymphalidae, Lycanidae, Riodinidae, and Hesperiidae.

Majority of the butterflies are habitat generalists, but there are some deviations (De Vries, 1988). Habitat generalists records throughout their range. But specialists are restricted to preferred habitats. Heterogeneity of vegetation is high in habitat edges with mixed characters of bordering habitats. These areas are known as ecotones. Butterfly composition also shows

a marked change in ecotones including a high Beta turnover (Pinheiro and Ortiz, 1992., Kerr et al., 2001., Collinge et al., 2003).

Disturbance to the vegetation create a change in the spatial scale. Therefore, there is a high habitat heterogeneity in disturbed habitats. Previous studies had shown that biodiversity increase after a moderate disturbance, but it decreased in large disturbances (Dumbrell et al., 2008). Thus, occasionally disturbed forest had high abundance, species richness, diversity and temporal variation in diversity than undisturbed forests. Species richness is positively correlated with canopy openness of these disturbed habitats (Willott et al., 2000). But undisturbed canopy record more canopy dwelling butterfly species than disturbed canopy (Addai and Baidoo, 2013., Houlihan et al., 2013). Thus, canopy loving butterflies are abundant in undisturbed forest areas.

Climax forest butterfly fauna is more shade preferring; also they are geographically restricted. Mobility of these butterflies is minimal compared to common forest dwelling butterflies (Leimar et al., 2003). Therefore, these species have low potential to re-colonize in another area and logging increases geographical restriction of these species. But more light preferring butterflies have wide geographical distribution. They are habitat generalists and found in disturbed habitats also (Spitzer et al., 1993., Hammer et al., 2003., Malabika, 2011., Houlihan et al., 2013).

Regenerating forests with different succession stages in between mature forest and human settlements provide a good spectrum of habitats to study the variation of butterfly composition with habitat types. The main objective of this study is asses and compare the composition butterfly community in two adjoining forest patches in different succession stages.

2. MATERIALS AND METHODS

Study Site

Maragamuwa FRSS, is located near Maragamuwa village bordering Naula – Elahera trunk road in Matale district, Sri Lanka. The FRSS is in intermediate zone at an elevation 369m above sea level, with mean annual rainfall of 1750 mm to 2250 mm, and a mean annual temperature of 27^0C. The western side of the FRSS is bordered by the natural forest (Kumaragala Forest Reserve- a conservation forest managed by the Forest Department (FD) of Sri Lanka) while the rest is surrounded by home gardens and slash and burn cultivation lands. The FRSS was established in a 60 ha block of harvested eucalyptus plantation, managed until 2005 for fuel wood used in tobacco curing by the Ceylon Tobacco Company (CTC). The land was leased to CTC for a 30 year period by the FD. At end of the lease agreement, the land has been returned to the state in 2010. In 2005 CTC has initiated a biodiversity restoration project in Maragamuwa plantation; in order to understand the patterns of plant colonization, and factors influencing the development of forest and its associated biodiversity (Figure 1).

The 10 year old forest blocks undergoing natural regeneration was selected as early secondary forest (ESF) to this study. The vegetation structure of the ESF mainly consists of small trees and shrubs. The 30 year old *Eucalyptus*- natural forest edge was selected as late secondary forest (LSF). Vegetation structure of the LSF is more complex than ESF with the highest floral diversity over the mature forest and plantation (Alahakoon et al., 2006).

Data Collection and Analysis

Line transect method was used to collect butterfly abundance data. Total of ten transects of 100 meters long were established in two forest types (five transects in each). Butterflies were observed for 20 minutes in each transect. All individuals visible were recorded except behind the recorder. Butterflies were identified in the field using guides of D'Abrera (1998). All data was recorded in a pre-prepared data sheet. Morning hours were spent to data collect, as butterflies are mostly active (Marchiori and Romanowski, 2006).

Three fundamental methods were used to measure the alpha diversity (α) of FRSS. Diversity indices, rarefaction curves and non-parametric species richness estimators were those three basic methods. Diversity based on species richness was estimated using Margalef index (D_{Mg}) and Hill's N_0 index. Shannon index (H') measures the species diversity of an area based on the proportional abundances. Evenness is the measure of the relative abundance of the different species making up the richness of a habitat. Rarefaction curves were drawn to determine whether sampling effort was sufficient to accurately study the community. Recorded field data were randomized 100 times to obtain a smooth curve. Accumulated species numbers were plotted against the sampling effort to generate species accumulation curves. To check the distinctness of species richness in two study sites, upper and lower bounds of 95% confidence were plotted in a same graph. Chao 1, Chao 2, Abundance Coverage Estimator (ACE), Incidence Coverage Estimator (ICE), Jackknife 1, Jackknife 2, Bootstrap were the used as non-parametric estimators to estimate the maximum species richness. The most suitable estimator was selected with the resulting estimates.

ANOVA test was done to identify the variation of butterfly abundance and number of species between two habitats. And T test was carried out to identify the difference of butterfly diversity among two forest types. Indicator species were recorded for both early and late secondary forests. Geographical distributions of butterflies were compared with the published geographical ranges of

the species by Gamage (2013). Rarefaction curves and non-parametric estimations were generated using 'Estimate S' software. Diversity indices were calculated using 'PAST 3' software. ANOVA tests and T tests were done using Minitab 14 software.

3. RESULTS

Field sampling was carried out for 24 months from June 2013. A total of 5,438 butterflies of 100 species in six families were recorded. ESF had high butterfly abundance recording 2,963 individuals in 70 species of six families. LSF had high butterfly species richness (76 species) in six families with 2,475 individuals. Of the recorded butterfly species, most were in the Least Concern (n=79) category, while 12 Near Threatened species and 9 Threatened (8 -Vulnerable (VU), 1-Endangered (EN)) with 4 endemic species (MOE, 2012). High butterfly species richness, diversity, and evenness were recorded in LSF while ESF had high abundance (Table 1). There was a statistically significant difference in butterfly diversity in two habitats. LSF had high species diversity compare to ESF (p<0.001).

The ratio of species to individuals was high (i.e. number of species for 100 individuals) at the early stages of the study. But, it was decreased with sampling effort. All common species were recorded at the early stage and rare species were recorded in later. Furthermore, 95% confident interval areas of each study site overlap with each other (Figure 2). Bootstrap was the most suitable non parametric species richness estimator as it gave values closer to the observed species richness of the area (n= 81/ESF, n=86/LSF).

Table 1. Within in habitat (Alpha) diversity of two study areas

Index	ESF	LSF
Shannon (H′)	2.83	3.40
Simpson (D)	0.11	0.05
Dominance (1-D)	0.89	0.95
Fisher_alpha	13.54	15.57
Hill's N_0	73	79
Margalef (D_{Mg})	9.01	9.98
Evenness	0.23	0.38
Equitability (J)	0.66	0.78

Table 2. Indicator species recorded in each forest succession stage

LSF	ESF
Common jay (*Graphium doson*)	One-spot grass yellow (*Eurema ormistoni*)
Tree nymph (*Idea iasonia*)	Plain tiger (*Danaus chrysippus*)
Commander (*Moduza procris*)	Common lasker (*Pantoporia hordonia*)
Baron (*Euthalia aconthea*)	Tawny costor (*Acraea violae*)
Nawab (*Polyura athamas*)	Forger-me-not (*Catochrys opsstrabo*)
Black rajah (*Charaxes solon*)	Banded Blue Pierrot (*Discolampa ethion*)
Transparent 6-Lineblue (*Nacaduba kurava*)	Pea Blue (*Lampides boeticus*)
Monkey-puzzle (*Rathinda amor*)	Opaque 6-Lineblue (*Nacaduba beroe*)
Golden Angle (*Capronaran sonnettii*)	Tailless Lineblue (*Prosotas dubiosa*)
Tricolour Pied Flat (*Coladenia indranii*)	Peacock Royal (*Tajuria cippus*)

Table 3. New locality records of butterflies

Family	Species	Common name	National Conservation status[1]
Pieridae	*Cepora nerissa*	Common gull	LC
	Appias albina	Common albatross	LC
	Ixias pyrene	Yellow orange tip	LC
	Eurema blanda	Three-spot grass yellow	LC
	*Eurema ormistoni**	One-spot grass yellow	VU
Nymphalidae	*Idea iasonia* *	Tree nymph	VU

	Euploea klugii	Brown king crow	LC
	Parthenos sylvia	Clipper	LC
	Libythea myrrha	Club beak	VU
Lycaenidae	*Discolampa ethion*	Banded Blue Pierrot	LC
	Jamides bochus	Dark Cerulean	LC
	Nacaduba beroe	Opaque 6-Lineblue	EN

* Endemic species

[1]Based on the national Red List 2012 of Sri Lanka (MOE, 2012)

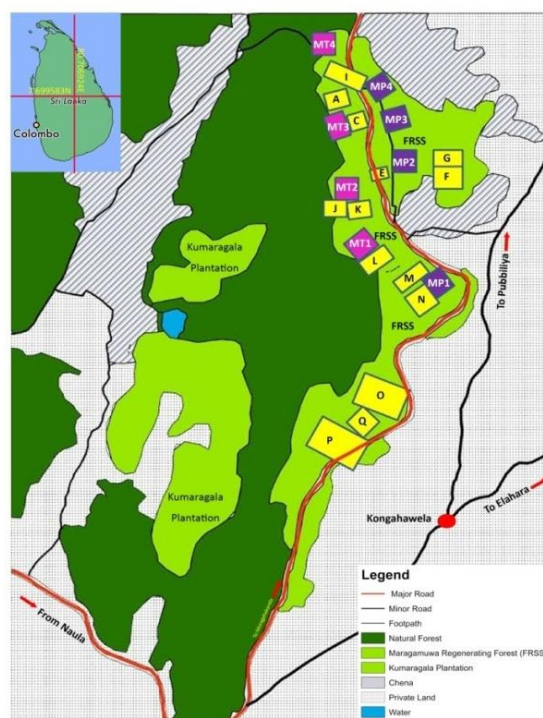EN- Endangered, VU- Vulnerable, LC- Least concerned

Fig 1. Location and block map of the study area
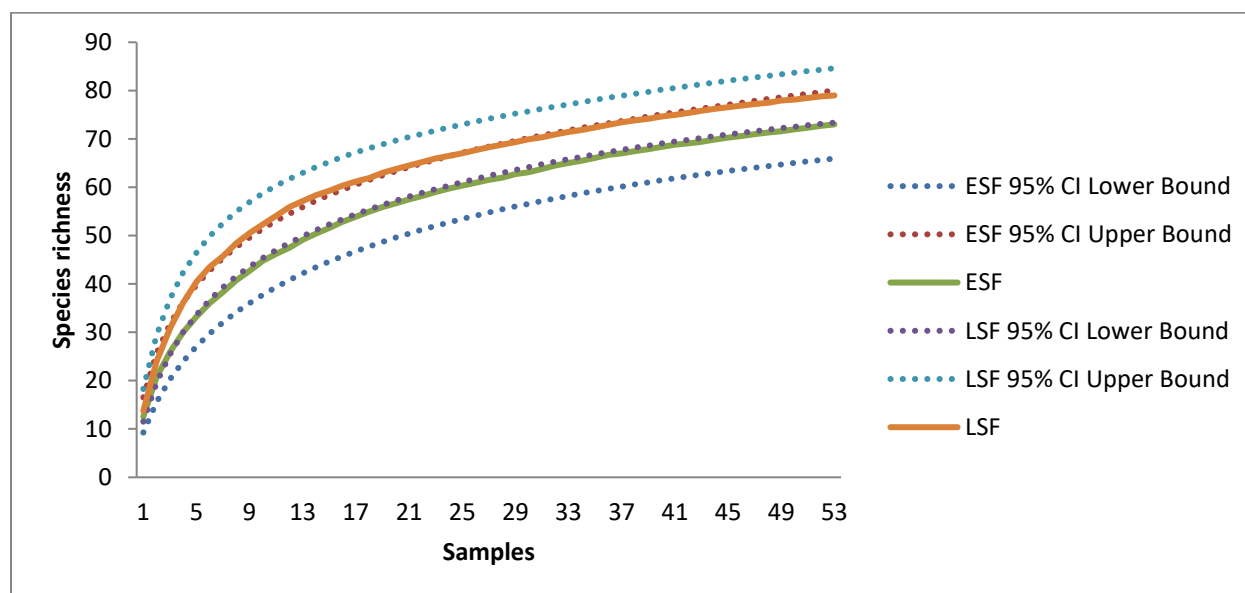(Source: Ranawana *et al.*, 2017)

Fig 2. Species recovery curve for sites

Nymphalidae was the most abundant butterfly family followed by Lycanidae and Pieridae. Riodinidae was the least recorded family in both forest areas. Over 50% of total abundance was represented by Nymphalid and Lycanid butterflies. ESF was dominated by White four-ring (*Ypthima ceylonica*) and the LSF was dominated by Common crow (*Euploea core*). Furthermore, Common crow (*Euploea core*) was the most abundant butterfly species in FRSS.

Indicator butterflies were identified with their habitat specific behaviors (Table 2). Majority of indicator species for LSF were large in body size and had rapid flight. But indicator species for ESF were small butterflies. Most of the threatened species represent as indicator species also. Lycanid indicator species were common to ESF while Hesperiid indicator species were common to LSF. Twelve new species recorded as new species for the region during the study (Table 3).

4. DISCUSSION

ESF has more butterfly preferring characters such as food resources facilitate high abundance, but high habitat heterogeneity in LSF drives to high species richness and diversity. Addai and Baidoo (2013) had recorded the highest butterfly diversity and richness in forests with undisturbed canopies. Furthermore, Hill (1999) had recorded that butterfly heterogeneity is corresponding with the available types of habitats. Similar pattern was observed in the current study, with high butterfly diversity in LSF. But less diverse and evenly distributed habitats in ESF increase the presence of habitat generalists throughout the area.

Dumbrell et al., (2008) had proposed a model to explain the behavior of butterfly diversity after a disturbance to the habitat. They studied disturbed habitats of 3-80ha in extent, and emphasized the diversity increase in moderate disturbance for small spatial scales. Willott et al., (2000) also had recorded the same observations in small areas in Borneo. They recorded high abundance, species richness and diversity of butterflies in logged forest than primary forest. On the other hand, findings of current study showcase the temporal variation of the butterfly diversity after the disturbance. Diversity and species richness increase with the time from the disturbance, providing evidences from high diversity and species richness in LSF compare to LSF.

For few sampling efforts in the beginning of the study, species accumulation was fast in ESF than the accumulation of LSF. But at the end LSF reached to higher species richness. Many species recorded in ESF are habitat generalists and common. But more habitat specialists are restricted to LSF. Thus, common habitat generalists recorded in early part while rare habitat specialists recorded in afterwards. Thus the 95% confidence levels in rarefaction curves of two forest types overlap, the species compositions are not distinguish from each other. Even though indicator species recorded for each habitat, most of the species were recorded in both forests.

Non parametric estimators are one of the main methods to identify the species richness of a given habitat. Performances of these estimators vary according to the sampling method, sampling organism and sampling habitats. For the current study Bootstrap estimator gives the nearest species richness value for the observed number of species. But other estimators also used by in previous studies. Jackknife 1 had shown best performances to estimate benthic macro-invertebrates (Basualdo, 2011). But Melo and Froehlich (2001) had proposed Bootstrap is the best estimator to calculate species richness in benthic macro-invertebrates in tropical streams in moderate sample size. Also they suggest Jackknife 2 as alternative for moderate and small sample sizes.

Succession of the vegetation determines the butterfly assemblage of the habitat. Cleary and Genner (2004) had recorded large butterflies dominate the community just after wildfires in Borneo rainforests. After 1-2 years the assemblage dominates by specialist small butterflies. Current study proves and extends that even after 10 years from the disturbance large butterflies dominate the assemblage. Furthermore, current study strengthen the findings of Hamer et al., (2003), which high butterfly diversity recorded in unlogged forest than the adjoining disturbed forest in Borneo rain forests. Furthermore, Hamer et al., (2003) had recorded that shade preferring restricted butterflies adversely affected by logging while light preferring butterflies benefits from logging. Hence, these shade preferring butterflies are useful as indicators in mature forests. Findings of the current study highlight that the butterfly assemblage show same behavior throughout the tropical region.

Nymphalidae is the dominating butterfly family in many habitats over the globe (Addai and Baidoo, 2013., Chowdhury, 2014., Qureshi et al., 2014., Sengupta et al., 2014). Furthermore, most of Nymphalid butterflies are habitat generalists, only few species are habitat specialists. Wide range in the habitat preference of Nymphalids has increased the ability of them to occupy most of the habitats. Present study supports that with the evidences in regenerating forests of intermediate zone in Sri Lanka.

5. CONCLUSIONS

The butterfly diversity in the intermediate zone is high due to the mixed climate and vegetation characters. Present study recorded 100 butterfly species in a small area of 60ha. This encounters 40.8% of the total butterfly fauna in Sri Lanka. Even though two forest patches adjoining each other, there is a marked difference in abundance, richness and diversity, and even can found indicator

species. Furthermore, findings highlight the need of re-evaluation of butterfly distribution maps, and the importance of long term studies on assessing species diversity and distribution.

Authors' contribution

Buddhika Weerakoon- Primary author

Buddhika Weerakoon is the scholar of the study. He involved in the study by collecting field data, analyzing and writing of the paper.

Kithsiri Ranawana- Co author

Kithsiri Ranawana is the supervisor of the research and a professor in Zoology in University of Peradeniya, Sri Lanka. He is the main researcher of the Maragamuwa Forest Regeneration Study Site. He involved the study by research designing, guiding on field works, data collecting, analyzing and writing.

Conflict of Interest

The authors declare that there are no conflicts of interests.

Ethical approval

The Animal ethical guidelines are followed in the study for species observation & identification.

Data and materials availability

All data associated with this study are present in the paper.

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